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Content of Cd, Cr and Pb in Soil and *Amaranthus caudatus* Grown in Yamaltu-Deba Local Government Area, Gombe State, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author AKI designed the study, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author AS reviewed the all drafts of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

The concentrations of some heavy metals (Cd, Cr and Pb) were determined in top soil and (*Amaranthus caudatus*) samples from irrigated farmlands in Yamaltu, Gombe State, Nigeria, using Atomic Absorption Spectrophotometer (AAS). The results show that the heavy metals contents were higher in the soil than in the amaranths. The results also revealed the trend in soil metals concentration as Cd > Pb > Cr and for the plant as Cd > Cr > Pb. Transfer factors (TF) decreased in the following order: Cd > Pb > Cr respectively. The levels of toxic metals are within the tolerable levels except for Cd in *Amaranthus caudatus* which are higher than the Indian Standard recommended values (1.5 mg kg^{-1}) for human consumption. The high level of Cd place the consumers of this vegetable crop grown within the area at health risk with time unless an urgent step is taken to address this issue.

Keywords: Soil; Amaranthus caudatus; heavy metals; fertilizers; transfer factors.

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1. INTRODUCTION

Soil polluted with heavy metals due to Geologic and anthropogenic activities remains a great problem all over the globe especially in developing countries. Anthropogenic activities as agricultural processes, industrialization and domestic activities cause the increase of heavy metals in soils and plants grown on such soils. Plants' growing on these soils shows a reduction in growth, performance, and yield. [1] Explain that the main sources of heavy metals to vegetables crops are their growth media (Soil, air, nutrient solutions) from which these are taken up by the root or foliage.

Some heavy metals are significant in plant nutrition, either for their essential nature or their toxicity [2]. Explain that metals such as chromium, cobalt, copper, iron, manganese and zinc are essential with their known physiological and biochemical functions while lead and cadmium are non- essential with toxic effects and cumulative behaviour [3]. Consequent upon this, [4-6] explain that Heavy metals are non-biodegradable and persistent environmental contaminants which may be deposited on the surfaces and then absorbed in to tissues of vegetables. [4,5,7,8] pointed out that plants take up heavy metals by absorbing them from deposits, on the parts exposed from polluted environments as well as from the contaminated soils. However, [9] opined that the amount the plants absorb depends on the environmental condition, such as temperature, soil pH, soil aeration and the availability of the element in the soil.

Amaranthus species are cultivated and consumed as a leafy vegetable in many parts of the world. In Nigeria, it is a common vegetable which goes with all Nigeria carbohydrate dishes. [10] stated That Vegetables constitute essential diet components by contributing protein, vitamins, iron, calcium, and other nutrients which are usually in short supply. These species have extended period of germination, rapid growth, and high rate of seed production [11]. The excessive application of nitrogen and other inorganic fertilizers and organic manure to these vegetables can accumulate high levels of nitrate and other anions as well as heavy metal. And consequently their intake by humans and animals can pose serious health hazards. [12] severe, Cd exposures result in kidney and bone damage. Lead toxicity causes reduction in haemoglobin synthesis, disturbance in functioning of kidney, joints, reproductive and chronic damage to the central and peripheral nervous systems [13].

Vegetables mostly grown by irrigation are Amaranth, lettuce, cabbage, okra, tomatoes, onion, pepper, roselle, but there is no information on the level of heavy metals in the soils and the vegetables produced in Yamaltu, Gombe State. This study determined the contents of some heavy metals (Cd, Cr and Pb) in the soils and in edible portions of *Amaranthus caudatus*.

2. MATERIALS AND METHODS

2.1 The Study Area

Yamaltu-Deba Local Government Area of Gombe State, Nigeria (Fig. 1) is situated between latitudes 10° 27' N and between longitudes 11° 28' E and 306 M altitude above sea level in the northern Guinea Savannah ecological zone of Nigeria [14]. Its geomorphology comprises of greatly undulating plains and sediments.

The area is characterized by two distinct wet and dry seasons, with annual rainfall ranging from 700-1250 mm. the mean temperature ranges between 30 – 32°C [15].

2.2 Sample Collection and Treatment

Soil and Amaranthus leaves samples were collected from 12 irrigated farmlands in four different locations namely; Baure, Dangar, Kwadon and Kunji of Yamaltu-Deba Local Government Area of Gombe State, Nigeria. The samples were collected using the techniques described by [16]. The samples were collected at random; at each farm five sub-samples from the top layer were collected at a depth of 0 -30 cm using steel auger. The collected sub-samples were then pooled together to form a composite of each individual sample making 12 composite sample per location. The plants samples were washed with tap water first and then followed by double washing with distilled water [17]. The samples were properly labeled and transported to the laboratory in clean polythene bags for analyses. Both the soil and plant samples were analyzed for Cd, Cr and Pb as described by [18].

2.3 Soil Properties

Soil pH and Organic carbon were determined using standard methods. Soil pH was measured in suspension of 1:2 soil water ratios using

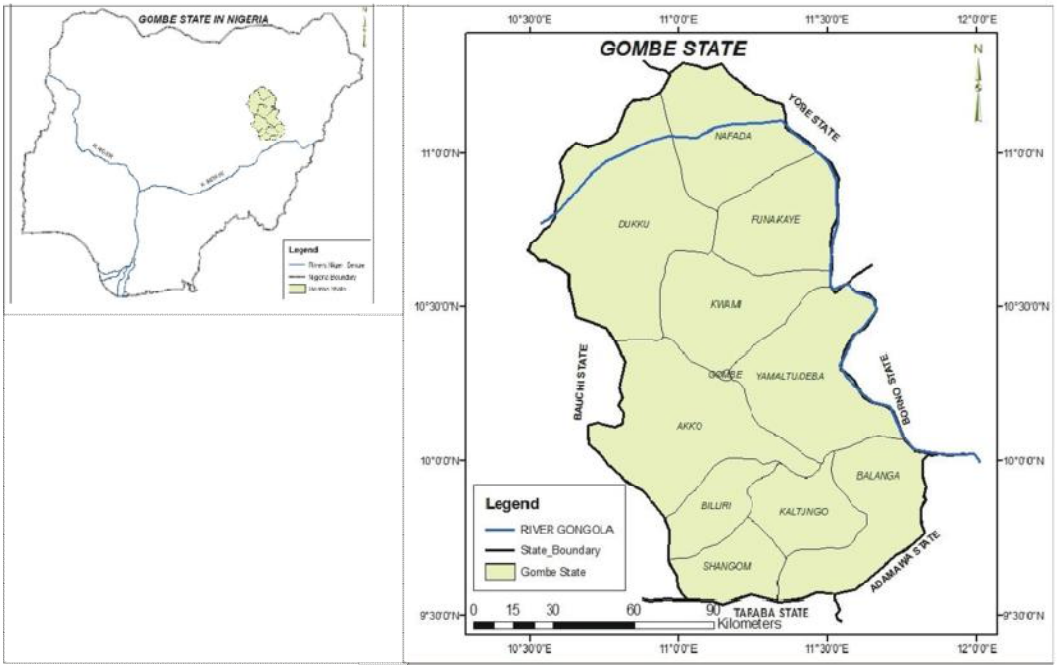

Fig. 1. Map of Gombe State and Yamaltu-Deba local government area

calibrated pH meter (Model ELE 160). Organic carbon content in soil was determined using Walkley and Black wet digestion methods.

2.4 Digestion and Analysis

Soil and sliced amaranths leaves samples were dried in an oven at 105°C for 24 hours until they were brittle and crisp [18]. A portion (2 g) of dried, disaggregated and sieved amaranth and soil samples were placed separately in 100 cm^3 Teflon beakers and then digested with 15 cm^3 concentration nitric acid at 550°C for about 3 hours, the digests were then filtered in to a 100 cm^3 volumetric flask. Level of Cd, Cr and Pb in the amaranths and soil samples digest were analyzed using Atomic Absorption Spectrophotometer (AAS) equipped with an air acetylene burner.

2.5 Transfer Factors (TF) for Heavy Metals from Soil to Vegetables

Transfer factor is the ratio of the concentration of heavy metals in a plant to the concentration of heavy metals in soil. The transfer factors (TF) for each heavy metal were computed as described by [19].

$$TF = \frac{\text{Element concentration in plant, dry weight (mg kg}^{-1})}{\text{Element concentration in soil, dry weight (mg kg}^{-1})}$$

3. RESULTS AND DISCUSSION

3.1 Physicochemical Parameters of the Soils

The results for some physico-chemical properties of the soils are shown in Table 1. In general, the results reveal the soils range from clay loam to loam in texture, slightly acidic to slightly alkaline in reaction and low in organic matter contents. Among soil properties, soil pH had the greatest impact on the desorption and bioavailability of heavy metals, because of its strong effects on solubility and speciation of heavy metals both in the soil as a whole and particularly in the soil solution [20]. The slightly low pH values in this study could be attributed to the constant application of organic fertilizers to the soils by the farmers to improve yields and as well as the decayed vegetable matters available in the soils. Apart from soil pH, OM was also one of the most important properties affecting heavy metal availability in soils for retaining heavy metals in an exchangeable form [21].

3.2 Concentrations of Cd, Cr and Pb in the Soils

The levels of heavy metals in the soils samples are presented in Table 2. Cd values range from 2.30±0.85 to 2.97±0.75; Cr, from 0.33±0.15 to 0.50±0.26 and Pb, 0.97±0.40 to 1.33±0.55. The order of accumulation of metals in soil samples was Cd > Pb > Cr. The elevated levels of the metals in the soil could be attributed to usage of fertilizers and other agro-chemicals, as well as the use of waste water in irrigating the soils and of course, the environmental factors in the areas [22]. The soils concentrations of these heavy metals were below the European Union [23] and Indian standard for soil permissible limits (Table 2). However, the results obtained in this study were higher than the values reported by [24] of heavy metals in the soils irrigated with waste water from beverages industry in Maiduguri, Nigeria.

At high concentrations, all heavy metals have also strong toxic effects on plants which results in chlorosis, growth inhibition, browning of root tips, yield depression, disorders in plant metabolism and finally death [25,26]. Heavy metals not only inhibit root growth but can also hamper many physiological processes and, in particularly, the uptake, transport and use of several elements (Ca, Mg, P, and K) and water by plant [27]. Inhibition of nutrient uptake will lead to nutrient deficiency and low in crop yield.

3.3 Concentrations of Heavy Metals in the Amaranth

The levels of heavy metals in the amaranth leaves are shown in Table 4. The concentrations of Cd ranged from 1.20±0.25 to 2.70±0.98; Cr from 0.24±0.15 to 0.30±0.20 and Pb from 0.51±0.41 to 0.80±0.24 dried weight of plant. The results reveal that the leaves of amaranth obtained in Yamaltu contain Cd, Cr and Pb in varied concentrations may be due to the peculiar type of agricultural practices in the area, such as the use of polluted water for growing of vegetables and the application of fertilizers and animal dung [24]. The order of contamination of the heavy metals in the spinach leaves samples were Cd > Cr > Pb. The concentration ranges of Cd, Cr and Pb in vegetables of this study are higher than the concentration ranges of Cd, Cr and Pb reported by [28] in lettuces growing in Kwadon. The values obtained in this study were lower than the Indian Standard [29,19] and NAFDAC standards for fresh vegetables maximum permissible limit of heavy metals except Cd (Table 2). However, the elevated levels of Cd in the vegetables obtained in the areas could be due to possible pollution as a result of the repeated use of nitrate and phosphate fertilizers and the agro chemicals such pesticides. There has been report that cadmium is a highly mobile metal, easily absorbed by the plants through root surface and moves to wood tissue and transfers to upper parts of plants. [30,31] elucidated that, there is a direct relationbetween the levels of presence of Cadmium in the root zone and its absorption by plant.

The level of heavy metals in plants depends mainly on the levels of soil contamination and plant species. A plant grown in a soil with a high level of a given heavy metals may likely contain high amount of the metals in its tissue. Similarly different plant species grown in the same soil may contain different levels of the same element. Some plants are hyper- accumulators, example cabbage [32] while others are mono accumulators of a given heavy metals. [33] Show that the concentrations of Cd in alfalfa, lettuce, radish and *T. caerulescens* increased with increases in doses of Cd in soil. At a given dose, the crops contain different amounts of the elements. At a dose of 100 µM of Cd in soil, the concentrations of the metal in alfalfa, lettuce, radish and *L. caerulescens* were 174.7, 157.7, 268.8 and 366.2 $mgkg^{-1}$ respectively. In a similar study, [34] noted that *Amaranthus* spp; Jute mallow and tomato grown in the same soil contain Cd, Cr and Pb in various concentrations.

3.4 Transfer Factor of the Heavy Metals from Soils to Plants

The transfers of the heavy metals from soil to the vegetables are presented in (Fig. 2.) Transfer factor (TF) is one of the key components of human exposure to heavy metals through the food chain. Transfer factors were computed for the heavy metals to quantify the relative differences in bioavailability of metals to vegetables or to identify the efficiency of a vegetable species to accumulate a given heavy metal [24]. These factors were based on the root uptake of the heavy metals and not the foliar absorption of atmospheric metal deposits [35]. The TF of the heavy metals from soils to Amaranth in this study were Cd (0.76), Cr (0.68) and Pb (0.56). TF greater than 1 indicates a very efficient ability to transport metals from roots to shoots, most likely due to efficient metal

Table 1. Physico-chemical properties of the study area

Location	Sand	Silt	Clay	Texture	pH	Oc
Baure	39	22	39	Clay loam	7.0	8.3
Dangar	26	16	58	Clay	6.6	7.0
Kwadon	49	22	29	Loam	6.4	8.1
Kunji	34	28	38	Clay Loam	7.4	7.6

Table 2. Guidelines for safe limits of heavy metals (mg kg^{-1})

Standards	Cd	Cr	Pb
European Union Standards for soil [23]	30	150	300
Indian Standard for soil	3 - 6	-	250 - 500
Indian Standard for vegetables	1.5	20	2.5
NAFDAC standards for fresh vegetables	-	-	2.0

Source: Awashthi [29], Abdulmojeed et al. [17] and European Union standards for soil [23]

transporter systems [36] and probably sequestration of metals in leaf vacuoles apoplast [37]. In (Fig. 2.) the Transfer Factors of all the heavy metals in the Amaranth leaves were less than 1. Variations in transfer factors among different vegetables may be attributed to differences in the concentration of metals in soil and differences in element uptake by different vegetables [19].

The rate of metal uptake by the plant could have been affected by other factors such as plant age, plant species, soil pH, nature of soil and climate [38]. The TF values showed that the order of uptake of metals by Amaranth is Cd > Cr > Pb. Cd had the highest TF and this is due to its high mobility [39]. The trend is in consistent with the results obtained by [40,34].

In heavy – metals - polluted soils some plant species are able to accumulate fairly large amounts of heavy metals without showing stress, which represents a potential risk for animals and human health because of transmission in the food chain [41]. Many people could be at risk of adverse health effects from consuming common vegetables grown in contaminated soils. For instance, prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney, bone diseases and cancers of various body organs are some of the reported effects of heavy metals poisoning [42].

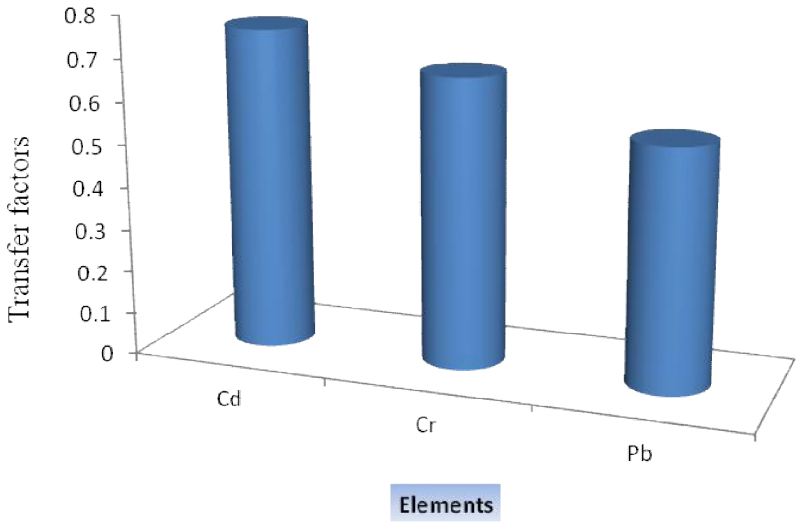

Fig. 2. The transfer factors (TF) of the heavy metals from soils to *Amaranthus*

Table 3. Mean concentration of heavy metal levels mg kg^{-1} in soils samples

Location	Cd	Cr	Pb
Baure	2.67±0.49	0.40±0.26	1.33±0.55
Dangar	2.97±0.75	0.50±0.26	0.97±0.40
Kwadon	2.73±0.90	0.33±0.15	1.33±0.76
Kunji	2.30±0.85	0.40±0.20	1.13±0.64

Table 4. Mean concentration of heavy metal levels (mg/kg^{-1}) in *Amaranthus caudatus*

Location	Cd	Cr	Pb
Baure	2.00±0.50	0.24±0.15	0.51±0.41
Dangar	2.30±1.06	0.29±0.20	0.53±0.20
Kwadon	2.70±0.98	0.30±0.20	0.80±0.24
Kunji	1.20±0.25	0.29±0.15	0.53±0.40

4. CONCLUSIONS

The results indicate that the concentration of Cd, Cr and Pb in the soil samples were generally lower than the Indian Standard, European Union Standards maximum permissible limits. On the other hand, in amaranth, the concentrations of Cd were higher than the Indian Standard maximum permissible limits. However, in this study, the soil-to plant Transfer Factor (TF) for various metals and for amaranth crops showed that the TF values showed that the order of uptake of metals by Amaranth is Cd > Cr > Pb. The slightly high levels of Cd in amaranth could be ascribed to possible contamination as a result of the vast agricultural activities going on in the area. This puts the consumers of these and other amaranth crop grown within these areas at health risk with time and as such regular monitoring of soils and the water used for irrigation is needed.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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